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Jan. 28, '05

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PUGET SOUND POWER COMPANY

PUYALLUP PLANT

Compliments of

STONE & WEBSTER

621,3 P96

Puget Sound Power Company

DESCRIPTION OF WATER-POWER DEVELOPMENT AND TRANSMISSION PLANT ON THE PUYALLUP RIVER, PIERCE COUNTY, WASHINGTON

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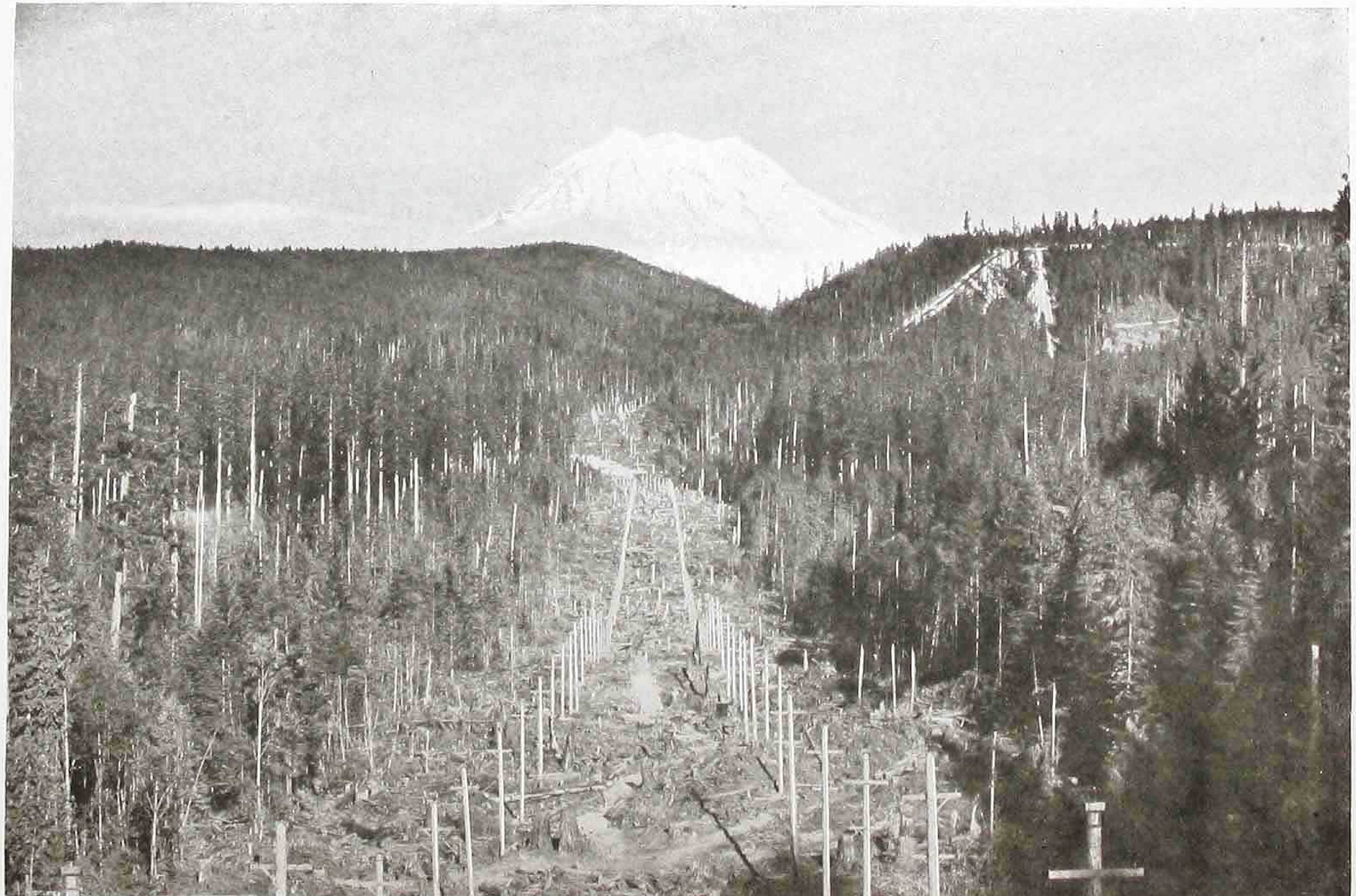
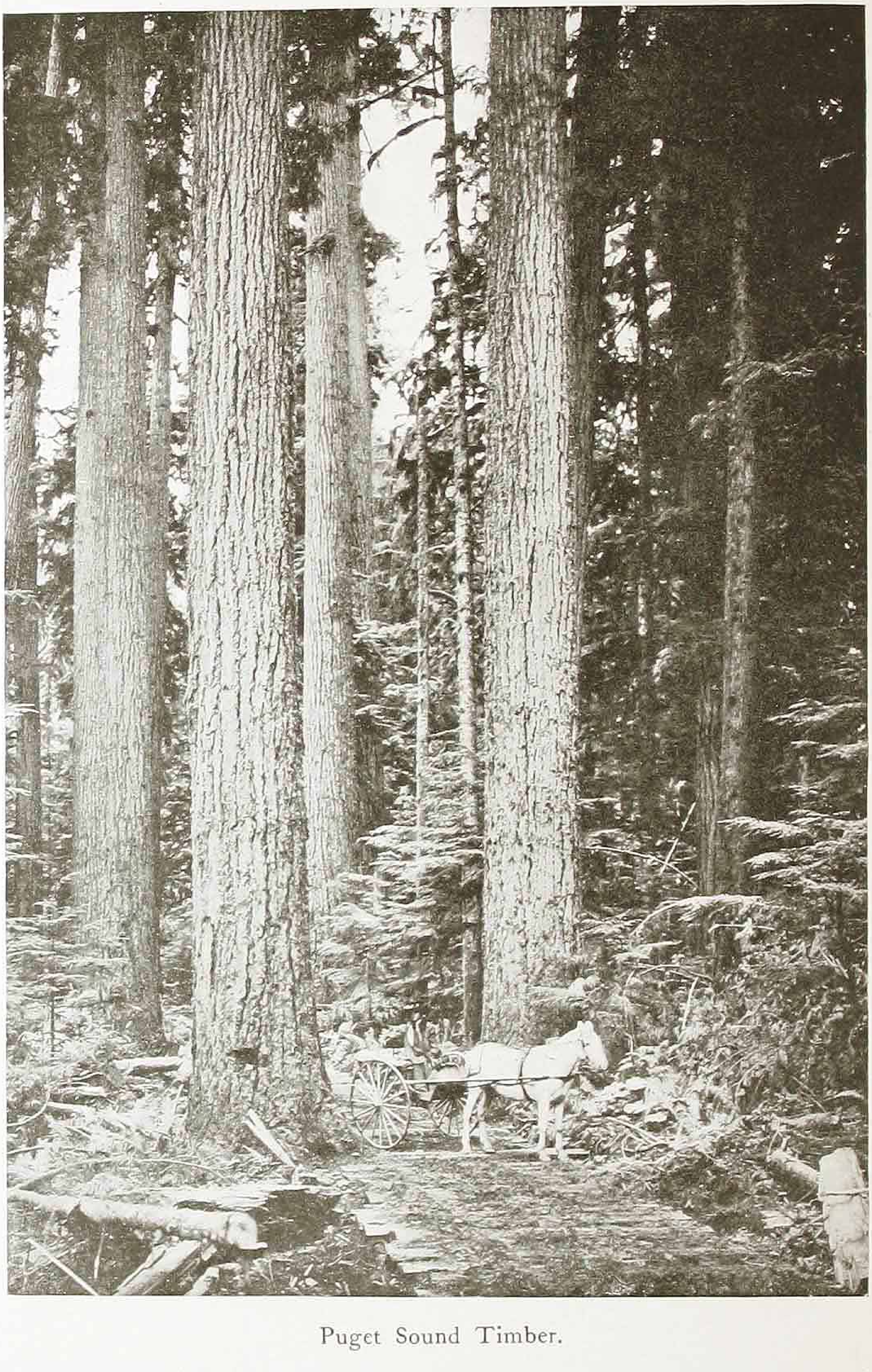


Mount Rainier.
On the Right the Hill back of Power House, Reservoir, Pipe Lines, Cable Incline and Wagon Road.
The Transmission Line in the Foreground.

PUGET SOUND POWER COMPANY.

That the country immediately adjacent to Puget Sound is to be one of the great industrial and commercial centres of the world there is every reason to believe. Geographically, it has an unsurpassed position of industrial and commercial importance, with untold wealth of resources. The future of the Puget Sound country is not entirely a matter of surmise. The past and present give a definite basis for calculation. The Pacific North-west is no longer an unknown quantity: it has shown what it can do while still almost undeveloped. Young as it is, it has passed through the "boom" stage of a newly opened country, and has come out a prosperous and impressive factor in national life. Within fifty years the State of Washington was a wilderness. Now it has more than three-quarters of a million of people, with property of an assessed value of nearly $300,000,000. It was admitted to Statehood barely fifteen years ago, yet already has upward of a hundred flourishing incorporated cities and towns. It first entered into foreign traffic during the last decade, and now requires the largest freight ships ever built for ocean service. The exports from the Puget Sound ports have increased from $4,364,000 in 1888, $5,090,000 in 1893, $17,920,000 in 1898, to $32,500,000 in 1903,—only $1,000,000 behind the exports from San Francisco for 1903.

The advantages that the Puget Sound country possesses as a commercial centre are sufficiently plain. Our Pacific coast, unlike our Eastern seaboard, although high and rocky, has but four harbor centres,—San Diego and San Francisco in California, the mouth of the Columbia River in Oregon, and Puget Sound. The more southerly of these, and much the older,—whether one counts their three centuries of history or only the fifty years since the discovery of gold,—had a great handicap in their favor when the younger entered the race for trade; but in ten years they have been almost overtaken, and, apparently, must soon be left behind. Puget Sound is a land-locked sea so deep that the largest vessels can touch its shores at any point. It is sheltered from storm, yet easy of access from the Pacific Ocean. The vigorous young cities on either hand, up and down its 1,600 miles of shore-line, make practically one great port fit to receive the growing commerce of a thousand years. It is nearer than San Francisco to the millions in the awakened Orient. Compared with Liverpool via the Suez Canal, it is 5,000 miles nearer to Hong Kong; while its docks bring New York 1,400 miles closer to the Chinese coast than any port in Europe. Australia and Oceanica are nearer this great harbor centre of the North-west than to London; and China, Japan, and Siberia are thousands of miles closer; while Alaska, that great country of undeveloped wealth, lies at its door. Already four great railroad systems stretch out across the continent behind it to the north-east, east, and south-east, drawing to its doors the



Puget Sound Timber.

traffic of both the Old World and the New, and carrying back again the imports of the Orient.

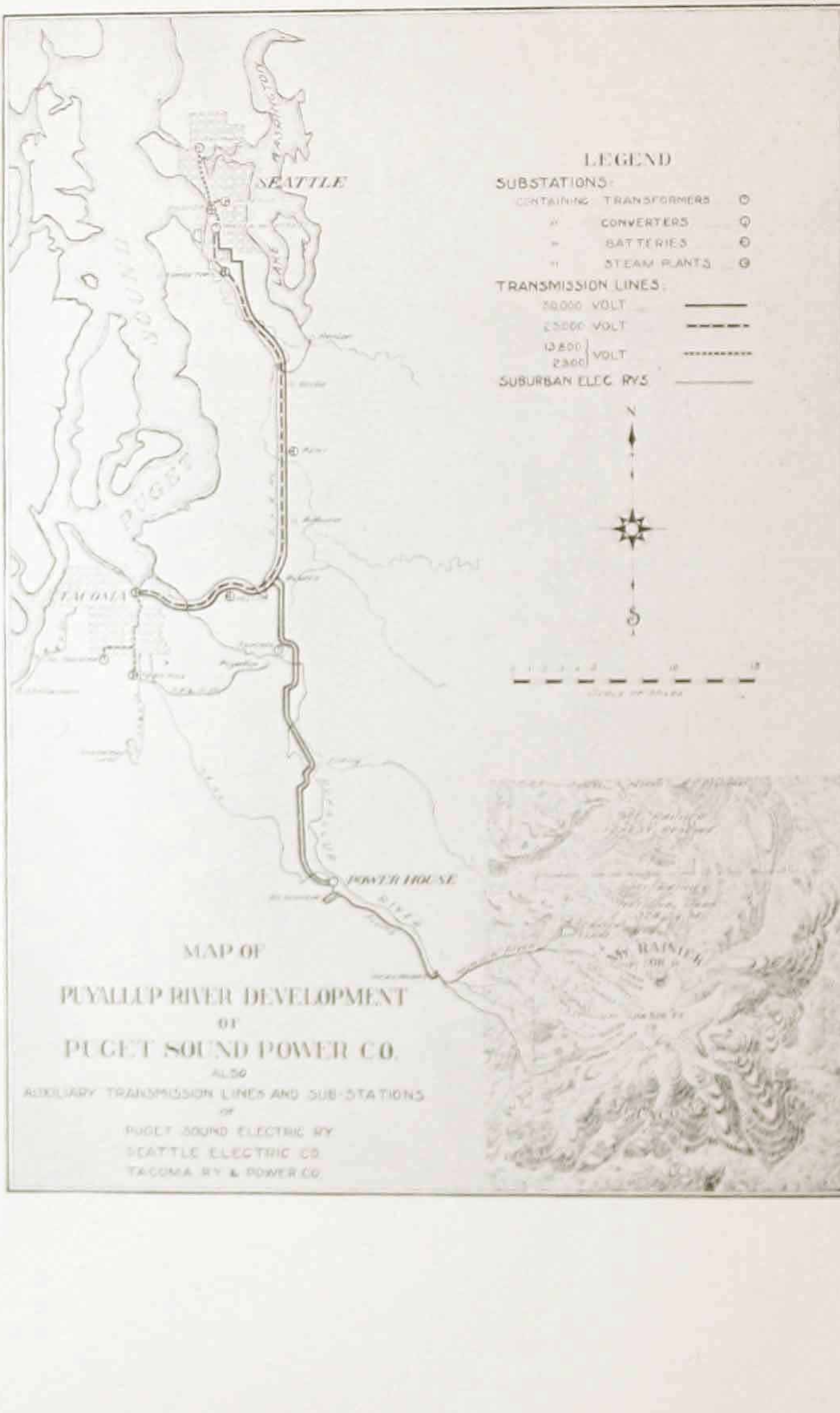
These advantages of geographical situation, great as they are, would count for less, however, but for the natural resources back of them which have played such a part in the magnificent development that has already been realized. The greatest forests in the world cover the slopes of the mountains about the Sound, and stretch inland many miles. Of the 42,800,000 acres in the State of Washington, 22,000,000 are covered with timber. The last geological survey estimates the standing timber in the State to be over 195 billion feet—enough to last 100 years with an annual cut of 2 billion feet, without touching the natural replacements during that period. Of the 20,000,000 untimbered acres, but 3,000,000 are under cultivation. Millions of acres of fertile land favorable for crops and pasturage lie still untouched, while the mineral deposits distributed throughout the State—gold, silver, coal, iron, marble, onyx—have not been developed beyond the point of proving the richness of their promise.

Already the products of Washington are going out to Asia, Africa, the Pacific Islands, South America and Europe, as well as through the length and breadth of our own continent. They are, for the most part, what nature has set ready to the hand of man; for, in the eagerness of the new Commonwealth to get its start well and quickly, they were the most available. But, with the improvements now under way, especially with

the provision of economical power,—the latest and, in some ways, most important step forward undertaken by recent enterprise,—manufacturing, but just beginning to exceed the home demand, is bound to grow in the next few years at the same extraordinary pace that marks the whole progress of the Pacific North-west.

Of the Pacific coast cities, Seattle and Tacoma, situated on Puget Sound, stand out conspicuously as the growing commercial and manufacturing centres. They are also leading ports of export and import of a rapidly increasing foreign trade. Their population, with that of their suburban towns, has increased in the last five years from 130,000 to 265,000. The motive power to serve this large population for the purposes of electric traction, lighting, and manufacturing is furnished by The Seattle Electric Company, the Tacoma Railway & Power Company, and the Puget Sound Electric Railway, the latter operating an interurban third-rail system between the two cities.

The increasing need of additional power to meet the requirements of the fast-growing population throughout the region served led Stone & Webster, of Boston, who manage the properties mentioned, to plan for additional power which should be adequate for their existing plants, as well as for a surplus for commercial purposes. To this end the Puget Sound Power Company was organized in 1902 for the purpose of developing and selling the water power of the Puyallup River, which has its source in the vast glaciers of Mount Rainier, the highest mountain in the United States. Stone &


LEGEND
SUBSTATIONS:
CONTAINING TRANSFORMERS
" CONVERTERS
" BATTERIES
" STEAM PLANTS
TRANSMISSION LINES:
50,000 VOLT
25000 VOLT
13,800
2300 VOLT
SUBURBAN ELEC RYS
N
S
SEATTLE
LAKE WASHINGTON
PUGET SOUND
TACOMA
POWER HOUSE
PUYALLUP RIVER
MT. RAINIER
MAP OF
PUYALLUP RIVER DEVELOPMENT
OF
PUGET SOUND POWER CO.
ALSO
AUXILIARY TRANSMISSION LINES AND SUB-STATIONS
OF
PUGET SOUND ELECTRIC RY
SEATTLE ELECTRIC CO
TACOMA RY & POWER CO

Webster were the engineers of this undertaking, and the initial generating plant of 20,000 horse power was completed and put in operation in the summer of the present year; and the power generated transmitted electrically to Seattle, Tacoma, and their adjacent towns.

The following pages describe in detail this installation, which is among the largest and most important of water power development and electrical transmission.

The Puyallup River Water-power Development.

Before beginning the construction of the plant, a careful investigation was made of the variations in the flow of the several rivers in Western Washington, and of the other features which would affect the reliability of the service obtainable from each; and a general plan was then adopted for the development of this power on the Puyallup River, with an initial installation of 20,000 horse power, the plans being made and the greater portion of the work carried out on the basis of continuing the initial installation to an ultimate development of 40,000 horse power.

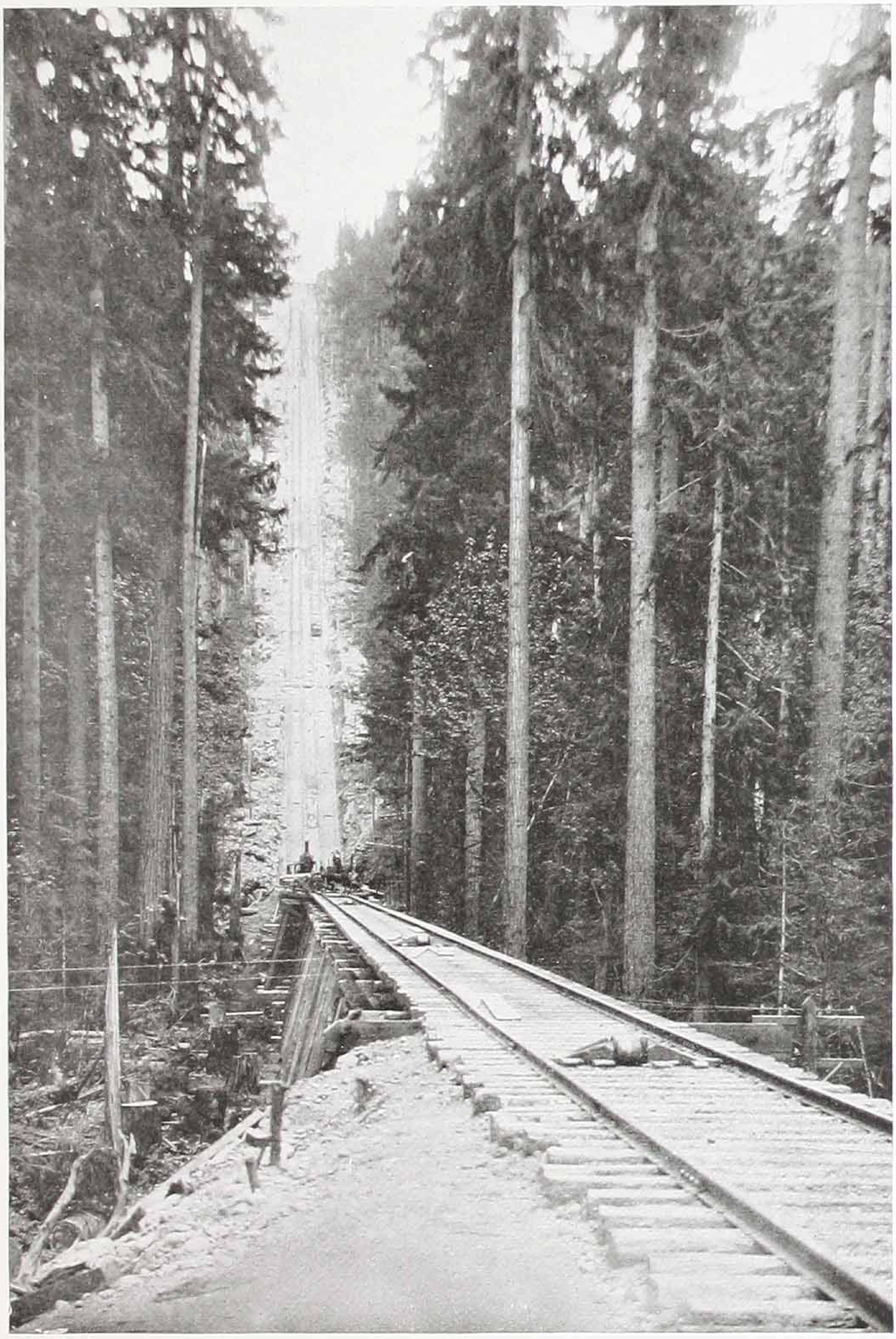
The design consists of diverting the Puyallup River just below the junction with the Mowich, and carrying the water by means of a flume ten miles to a reservoir located on a high plateau, and thence discharging by means of steel pipes against wheels in the power-house, under a head of 872 feet; the water wheels so driven being direct connected to electric generators, and the electric power

so produced being transmitted at a pressure of 55,000 volts, 48 miles to Seattle, and 32 miles to Tacoma.

All water rights and the necessary land abutting on the river from the point of diversion to point of return were secured, as well as all land necessary for flume and other structures; and actual work of development was commenced March 1, 1903. To facilitate construction, a spur track 2 1-2 miles long was built from the Kapowsin Station of the Tacoma Eastern Railroad to a new station at Electron, and continued a mile further to the power-house site. From Electron a standard gage cable incline was built to lift to the reservoir site at an elevation of about 950 feet above the power-house, and a wagon road to the head works. The first generator unit of 5,000 horse power was put into commercial operation, delivering power to Seattle and Tacoma, on April 14, 1904, less than fourteen months after work was begun. The plant was put into complete operation for its initial installation of 20,000 horse power on July 23, 1904.

Source of Supply.

The Puyallup River has its source in the glaciers of Mount Rainier, the highest mountain in the United States and one of the great mountain peaks of the world, covering 200 square miles and rising 14,500 feet above the waters of Puget Sound. Above an elevation of 5,000 feet the mountain is covered with snow and ice; and the precipitation, resulting from the contact of the moist-



The Cable Incline.

ure-laden air of the Puget Sound region with the glacial cold of the mountain-sides, is estimated to average 140 inches per annum. The fields of ice and snow formed by this precipitation move slowly down the mountain-sides to the valleys about its base in the form of glaciers many square miles in extent, filling the valleys to a depth of hundreds of feet.

These great masses of ice, increasing during the winter, melt away in the summer in proportion to the heat and dryness of the weather. The Puyallup and Mowich Rivers, draining a fan-shaped section of the mountain and five of the glaciers described, flow through mountain ranges rich in springs and streams, and join about twelve miles below the glaciers, taking the name of the Puyallup River. The water-shed of these rivers, below the higher mountain ranges, includes a rough and heavily timbered country, comparatively free from snow and ice. The streams of this lower timbered country are fed by the heavy rains of the Puget Sound district which occur in the cool weather of the fall, winter, and spring months. At this season the rain and the resulting run-off in the timbered section are heavy, while on the mountain the accumulated snow and ice give a correspondingly light run-off. When the warm weather comes, the rain and the run-off from the timbered section are at a minimum; and the melting of the snow and ice on the mountain and the run-off therefrom are at a maximum. This balance, or alternation of the heavy run-off from the timbered and ice sections, results in a remarkably uni-

form flow in the river at the point from which the water is taken for power purposes, and makes the operating conditions in using this stream ideal.

Although the dam and intake are located within 10 miles of the nearest glacier, the elevation at this point of diversion is only about 1,700 feet above the sea-level; and the climate at this elevation is so uniformly mild, and the water flows so rapidly, that no ice comes down the river, nor is formed either in the flume or reservoir.

Utilization of Current.

The power is used for all branches of service,—light, power, and railway. It supplies the electric railway systems in Seattle and Tacoma, aggregating 168 miles of trolley road; the multiple unit, third-rail line between Seattle and Tacoma; two cable roads, one in Seattle and one in Tacoma; furnishes power for numerous factories, together with the shops of the Northern Pacific Railway and the new pumping plant of the city of Tacoma; and the greater portion of commercial, residence and street lighting in Seattle and in the towns between Seattle and Tacoma.

Much of the power is distributed as alternating current; two-phase for power and single-phase for lighting. But there is also connected 10,000 kilowatts of converting capacity for producing direct current; 2,000 kilowatts of which is used for light and stationary motor supply. As the bulk of the converting machinery—7,300

Dam and Intake.

kilowatts—is of the synchronous type, it is not necessary for the water-power plant to generate or transmit idle currents.

The distribution of the current to the various localities, and the transformation and conversion for various uses, takes place at eleven sub-stations, containing 26,000 kilowatts of transformer capacity. Six of these sub-stations are designed for transforming the 55,000 volt current to lower voltages, and eight contain machinery converting to direct current for railway use.

Dam and Intake.

At a point one-half mile below the confluence of the Puyallup and Mowich Rivers, and about 1,700 feet above sea-level, is located the dam and intake of the Puget Sound Power Company. Here the water necessary for the operation of its plant is diverted, by a low, solidly constructed dam, through a masonry intake to a flume which is constructed on the south-west side of the river for a distance of ten miles. The dam or diverting weir is 200 feet long and 5 feet high, and covers the bed of the river longitudinally for a distance of 60 feet, exclusive of the down-stream apron. It is built down to an impervious bottom of clay hardpan, and is made tight by three rows of triple-lap sheet piling set into hardpan bottom, and bedded in concrete. It is faced with 6″x 12″ timber, covered at the crest with 1-4″ boiler-plates; and, besides the whole dam being a spill-

way, there is a lower spillway, 30 feet wide, to localize scour on intake side of the river. The intake is set at right angles to the dam, and is constructed of concrete masonry. It is 62 feet wide at the river-bank, and is protected by a screen grating made of iron bars 1-4″ x 4″ x 6′, spaced 2 1-2″. Provision is also made for the insertion of flash-boards in grooves in steel frames, in such manner as to regulate or entirely shut off the intake at a point between the river and the grating. A radial gate of unique design is also installed at the junction of the masonry intake and the flume for the purpose of quickly controlling the amount of water delivered to the flume.

Flume.

From head works to reservoir, a distance of about ten miles, the water is carried in a flume, which, as now constructed, is eight feet wide and five feet high inside measurements, but is framed for the addition of plank to a total height of eight feet. The flume is supported on low trestle work, which follows the contour of the land. This trestle work is of the same construction and strength as is used for railroads; and in fact, during the construction, heavy work-trains were operated over its entire length. The flume proper is constructed of surfaced planks 2 1-4″ in thickness and 12″ wide, supported on frames surrounding it at intervals of 4 feet. It is built on a uniform grade of 7 1-2 feet to the mile. Sand boxes and automatic spillways are provided at various points

Flume near Reservoir. Automatic Regulating Spillway.

One End of uncompleted Reservoir, showing Flume entrance and Forebay.

along the flume, and a number of gates for emergency use. A light railroad track for hand cars of standard gage is laid along the top of the flume to facilitate inspection and repairs.

The use of true curves instead of a series of tangents in following the bends in the flume insures smooth surfaces and small resistance to the flow of water, while the danger from slides and falling timber is minimized by supporting the trestle bends on rock or hardpan, and by the careful removal of the danger timber.

Reservoir.

The flume discharges its water into a reservoir located on a high plateau, nearly 900 feet above the power-house. This reservoir serves as a relay to maintain the plant in continuous operation in case of interruption of water supply, and is also very useful in supplying water for temporary overloads in excess of discharge capacity of flume; or, in other words, for equalizing the daily fluctuations of load. The location of the reservoir is particularly well adapted for the purpose. The material excavated from the higher side of the site was used to form the embankment on the lower side of the reservoir. This material is a glacial boulder till of clayey consistency, which requires blasting before it can be handled with steam shovel. It puddles well and forms a water-tight fill, which sets hard in embankment, almost like concrete.

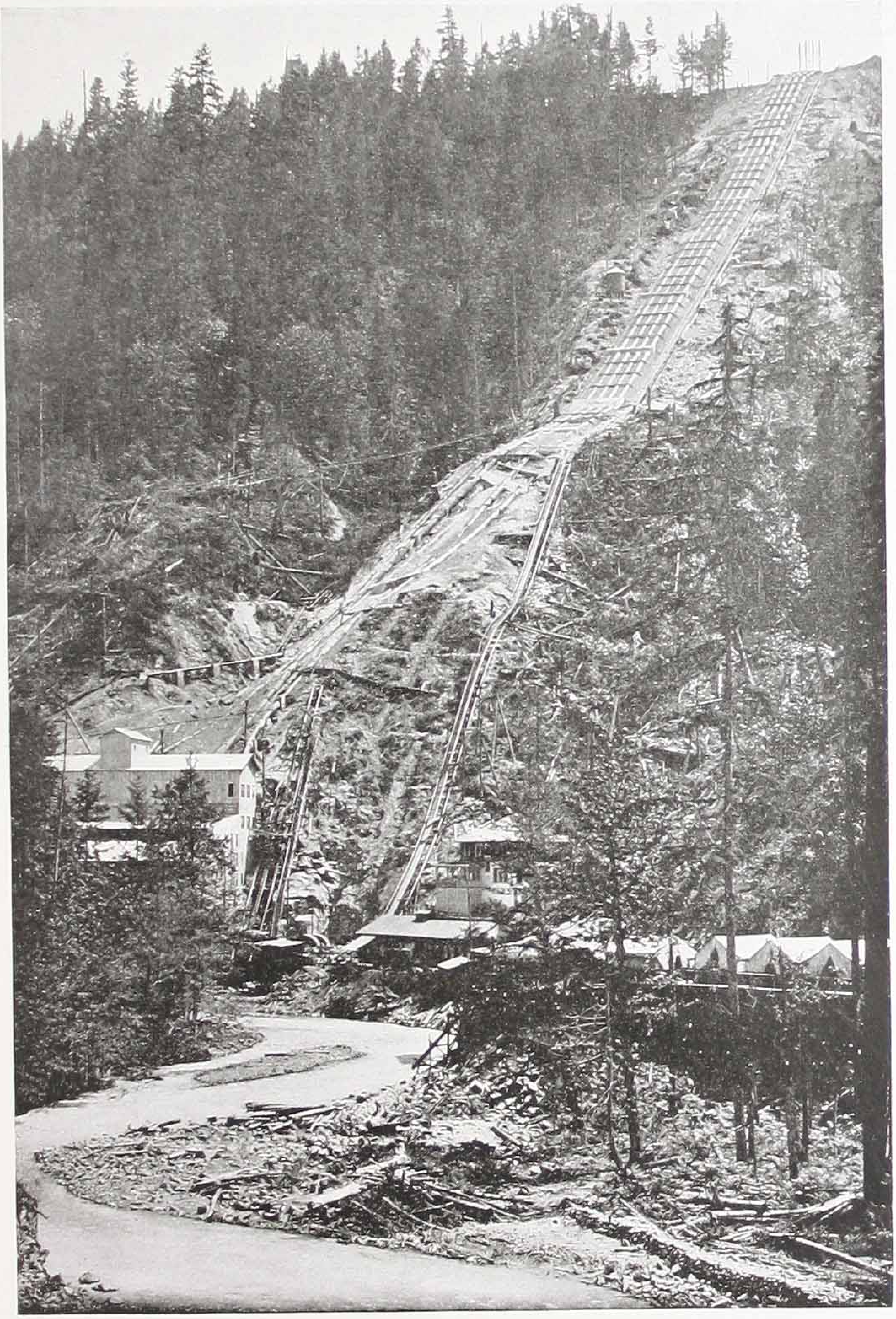
The flume enters one end of the reservoir, and, when the latter is drained, as shown in the illustration, discharges into a concrete basin in front of the forebay. This arrangement permits the emptying of the reservoir for inspection or cleaning without interrupting the delivery of water to the power-house, and distributes the water quietly to the penstocks without danger of carrying air into the pipes.

The forebay built inside of the reservoir is of concrete, divided into compartments forming separate gate chambers for the main penstocks. Each compartment is provided with iron racks or screens, with stop-boards to permit inspection or repairs without emptying the reservoir. The gates are arranged for connecting an electric motor drive to be controlled from the power-house.

The depth of water in the reservoir is at all times shown at the power-house switchboard by a Dibble automatic electrical indicating and recording water gage fitted with low-water alarm. This gage is operated by three wires running from a float-actuated Dibble transmitter at the reservoir.

Penstocks.

The penstocks, one for the two exciters, one for each of the four generating units now installed, and one for each of the remaining four units to be installed later, are carried through the reservoir embankment in the form of concrete protected wood stave-pipes, joining the steel pipes just outside the reservoir embankment. Of the



Penstocks.

Power House. West View.

eight main pipes for the complete plant, four, together with the exciter pipe, are now continued about 1,700 feet down an incline of about 30 degrees to the power-house on the river-bank below. Each main pipe is of riveted steel, 48 inches in diameter and 1-4 inch thick at the upper end, tapering to 36 inches in diameter and 3-4 inch thick at the lower end. The pipes were furnished by the Risdon Iron & Locomotive Works. The penstocks are anchored by massive concrete abutments, designed to drain all surface water away from the pipes. As a further security, the pipes are protected with backfilling of earth, on which is planted quick-growing vegetation.

Power-house.

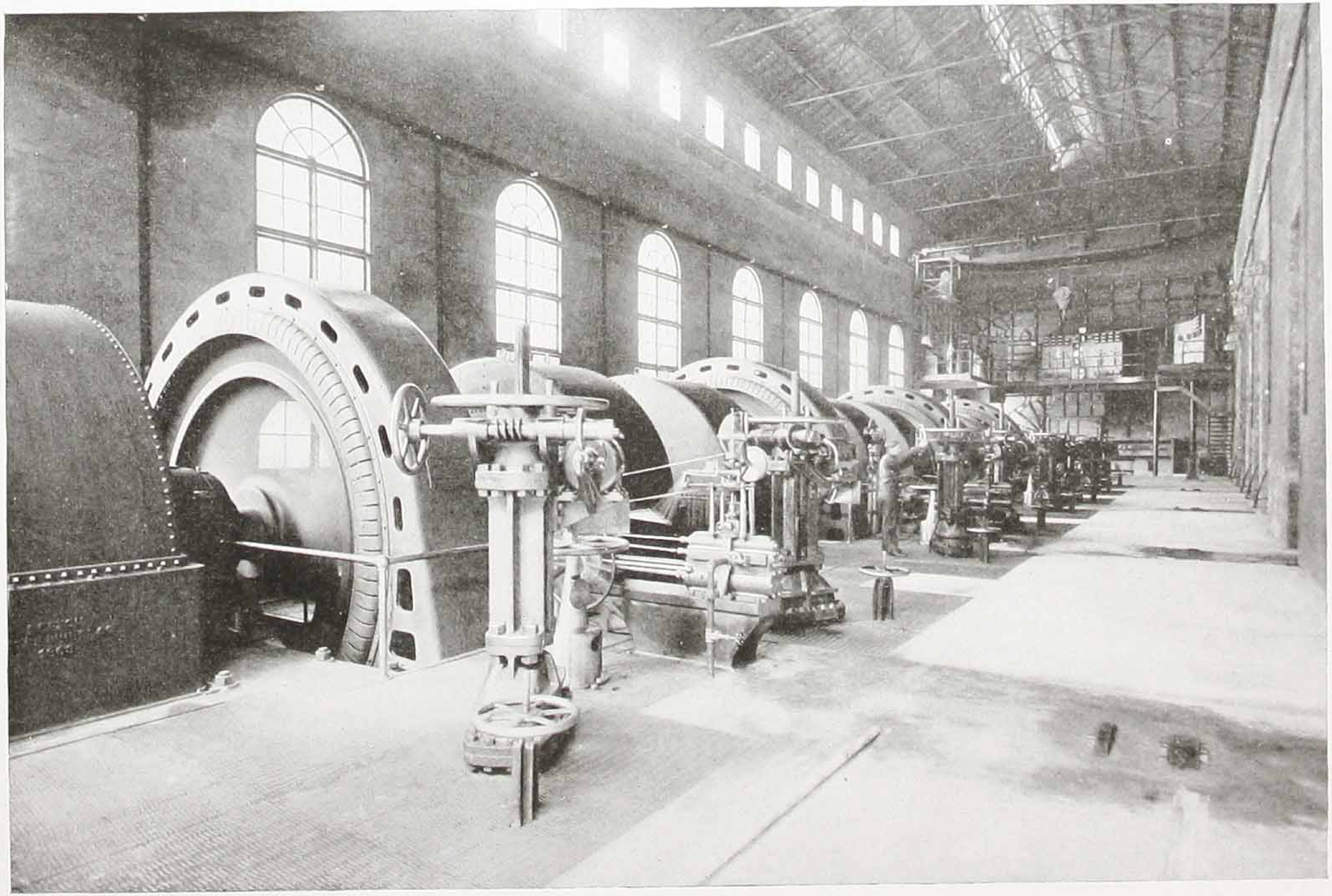
The power-house is a massive concrete, brick, and steel structure built in the bank of the river on a foundation of rock and piling. The building for eight units will be about 100 by 266 feet, divided longitudinally into two parts,—a generator-house and a transformer and switching-house. The generating units are arranged parallel to and along the river side of the building, the penstocks being brought to them under the main floor from the rear. The transformers are grouped in isolated rooms of concrete in the basement of the switch-house, the switching apparatus and wiring being in compartments overhead, as described.

Water Wheels.

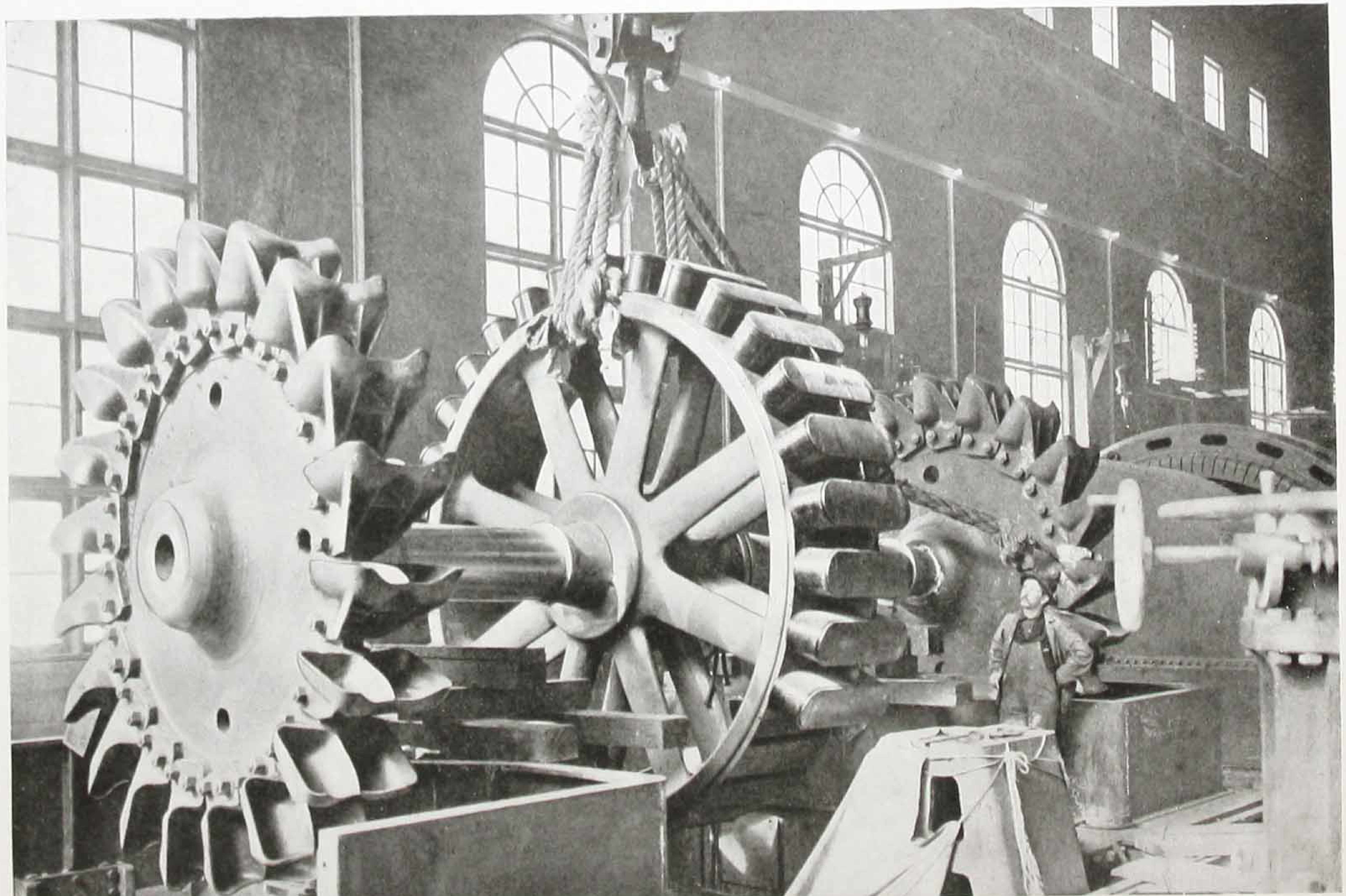
Each "unit" consists of two overhung Pelton water wheels, ten feet, six inches in diameter, mounted one on each end of the shaft of each 5,000 horse-power two-bearing generator. The nozzles are of the needle type, arranged for automatic deflection by Lombard Type "L" governors for speed control, the operation of the needles being for economic adjustment of the discharge to the load of the machine. Each nozzle is also provided with a motor-operated gate valve for cutting off the water supply. Each wheel "unit" has a maximum capacity of 7,500 horse power.

The wheels are arranged to be started, stopped, and adjusted for speed from the main operating switch-board at one end of the generator-room. Motor-driven pumps provide oil supply for ordinary lubrication, pressure oil for forced lubrication in starting and circulating water for cooling the bearings.

The rotors and wheels are hydraulically forced on to a 24-inch hollow nickel steel fluid compressed shaft. The spray from the wheel discharges, collecting in the water-wheel housing, enters this hollow shaft and automatically serves to cool the bearings. At the date of their installation these were the largest impulse wheel units in the world.



Interior Power House. Generator Room.



No. 3 Unit. Placing Water Wheel and Rotor Shaft in Bearings.

Generators.

There are four revolving field generators, made by the General Electric Company, of 3,500 kilowatt capacity each, with an overload capacity of 25 per cent. for two hours, wound for three-phase current at 2,300 volts, and a frequency of 60 cycles per second.

Exciters.

Two 150 kilowatt, 125 volt, 600 revolutions per minute, shunt wound exciters are provided, each direct connected to an overhung Pelton water wheel, and to a 2,080 volt, 200 horse-power, three-phase induction motor. The wheels driving the exciters are not provided with automatic governors, the direct connected induction motors serving this purpose, operating either as motors or generators, according as they run below or above synchronous speed. The motors also afford a relay source of power for excitation in case of failure of an exciter water wheel or its water supply. Each exciter is capable of exciting six generators under all conditions.

Transformers.

There are three banks of transformers installed at the power station, each bank consisting of three 2,333 kilowatt, water-cooled, oil-insulated General Electric Company transformers, with 25 per cent. overload capacity

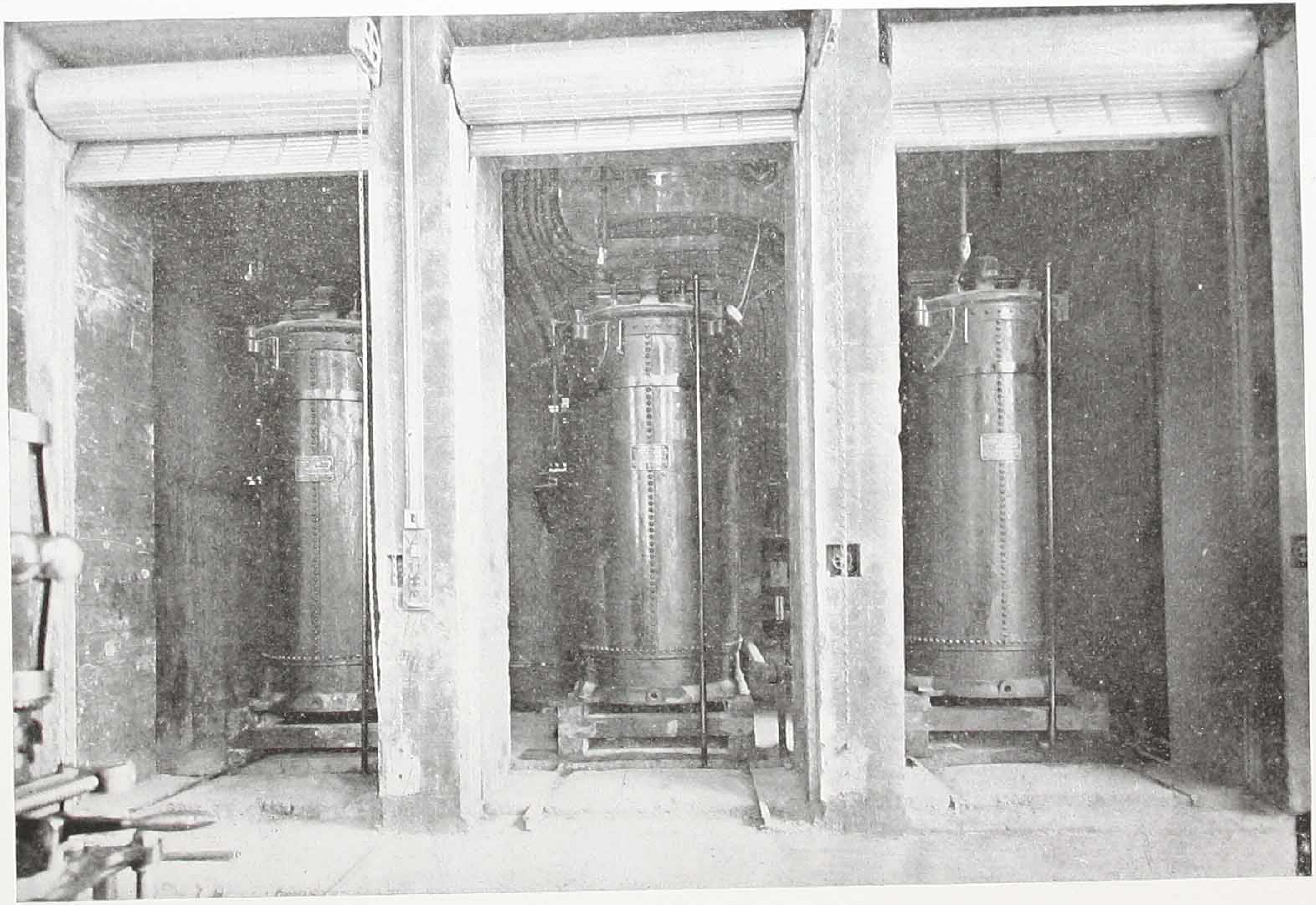
for two hours. Each bank has a capacity equivalent to two generators, the third bank being spare, so that the failure of even a complete bank would not diminish the capacity of the station. The transformers are connected delta on both the high and low tension sides; and the arrangement of the windings is such that, with 2,300 volts on the low tension side, high tension voltages of 27,500, 45,000, and 55,000 may be derived. These transformers have been operated at 55,000 volts from the beginning.

Water for cooling is obtained from a spring above the power-house, supplemented by connection with the reservoir. The transformers are piped so that the oil can be removed from the cases into large storage tanks or discharged in an emergency directly into the river.

Before filling these transformers with oil, they were dried out at a temperature of 80 degrees C. under a vacuum of 26 inches for 10 hours. No oil was used that did not stand a potential test of 40,000 volts between 1-2-inch flat electrodes placed 2-10 inch apart. After filling and allowing the oil to thoroughly settle, samples of oil from bottom and top of each transformer were subjected to the above potential test; and no transformer was put into service before the oil passed this test satisfactorily.

Electrical Arrangement.

For connecting each generator and transformer bank to the low tension bus bars and each transformer bank and transmission line to the high tension bus bars, a full



One of the Three Groups of Step-up Transformers.

complement of remote control, motor-operated oil switches is provided.

There are two sets of 2,300 volt bus bars, designated as the Main and Auxiliary busses. The Main bus is for regular operation, while the Auxiliary bus is for emergency operation and for relaying the Main bus in case of repairs to the latter. Both sets of bus bars are identical, and any generator and any transformer bank can be connected to either set.

Between each generator and each set of 2,300 volt bus bars there are two sets of disconnecting switches and a triple-pole General Electric Company's Type "H" 1,200 ampere motor-operated oil switch; one set of disconnecting switches being on either side of the oil switch. Between each set of bus bars and each transformer bank there are two sets of disconnecting switches and a type "H" 3,000 ampere motor-operated oil switch, the arrangement being similar to that of the generator switches. The purpose of the disconnecting switches is to remove the potential from the oil switches, that inspection of or repair to the oil switches may be safely made. The disconnecting switches are not to be operated when carrying current, except under emergency conditions. All ordinary switching is done by means of the oil switches, which simultaneously open and close the three legs of the three-phase circuit. In addition to the single-pole, double-throw switches mounted on the operating panels, for opening and closing these switches, when cutting in or out a generator or transformer bank, there

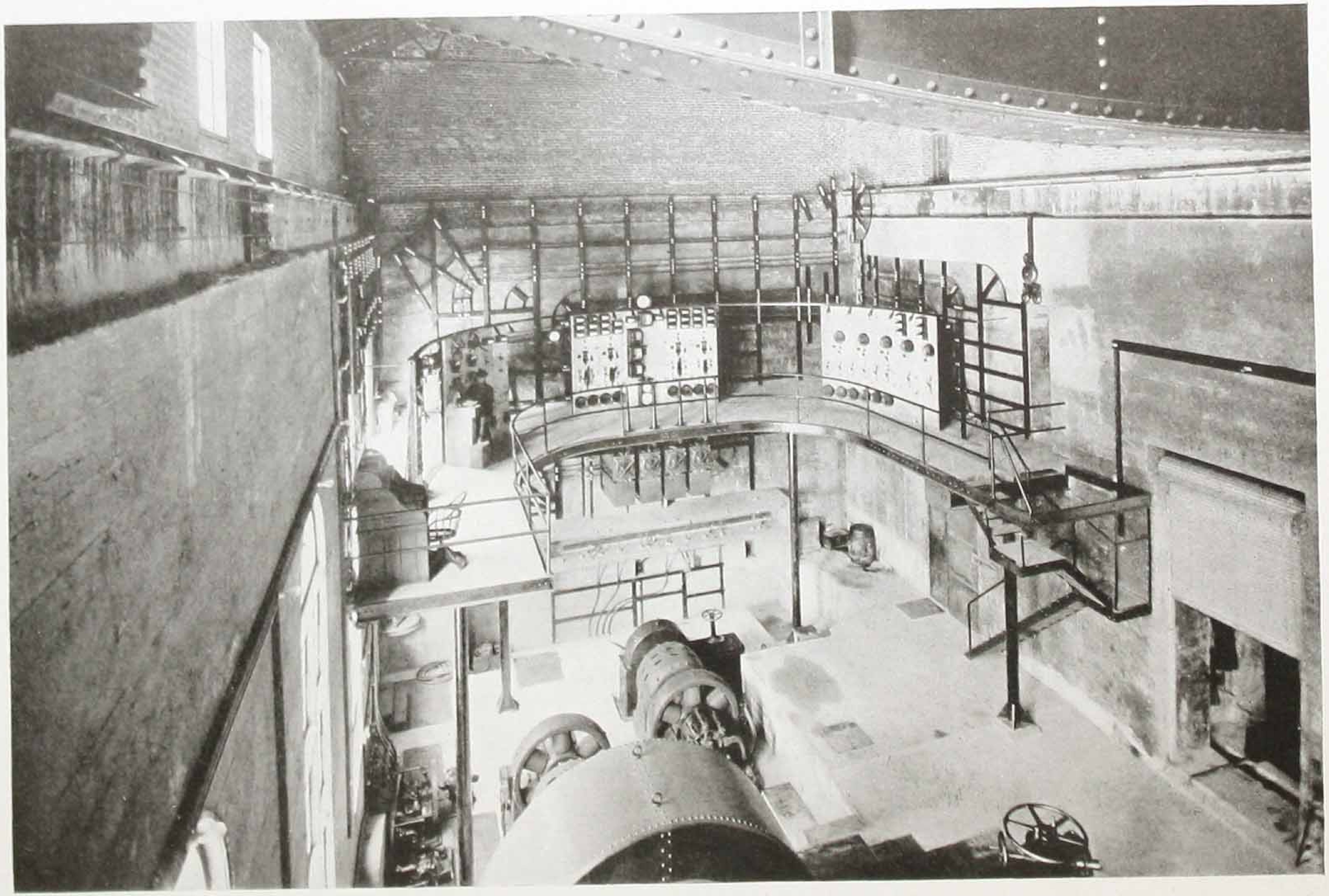
is for each oil switch a clock type time-limit relay actuated by secondary current from current transformers in circuit with that switch, these relays operating the motor connected to the oil switch in case of an overload or short circuit lasting the period for which the relay is set. These relays can be set for overload periods of four seconds down to a small fraction of one second, it thus being possible to automatically localize short circuits on the system, and in apparatus, without completely shutting down the system. The electrical arrangement of the motors driving the exciters is the same as that of the generators.

There is one set of high tension bus bars, divided into three sections by sectionalizing switches, each transformer bank being connected to a corresponding section, and one line to each of the end sections.

Between the high tension bus and each bank of transformers there are two sets of disconnecting switches and one triple-pole General Electric Company 60,000 volt, 400 ampere motor-operated oil switch; one set of disconnecting switches being on either side of the oil switch. There are two outgoing high tension lines, each line being controlled as just described for the transformer banks. All the high tension oil switches possess the automatic features as described for the low tension oil switches.

Lightning arresters without reactance coils are provided for each outgoing line.

Static dischargers are provided for the low tension side of each transformer bank. These static dischargers



Operating Gallery and Switchboard.

consist of three 2,500 volt, S. P. lightning arresters connected in star, the neutral point grounded. They limit the potential of the low tension winding to 2,500 volts above ground, and would come into action in case of grounding of one side of the transmission line or transformers.

The control of all the oil switches is from operating panels erected on a gallery in the east end of the generator-room, at an elevation of 14 feet above the generator-room floor. The arrangement of panels from left to right is:—

Exciter Panels, generator end.
Exciter panels, motor end.
Generator panels.
Totalling panel.
Generator panels.
Transformer control panels.
High tension line panels.

The generator and exciter field rheostats are hung below the gallery, and are operated from pedestals by means of shafting and bevel gearing, the contact plates being on the rheostat boxes.

The highest alternating current potential on the switchboard panels is 115 volts derived from potential transformers, and the highest direct current potential is 125 volts derived from the exciters.

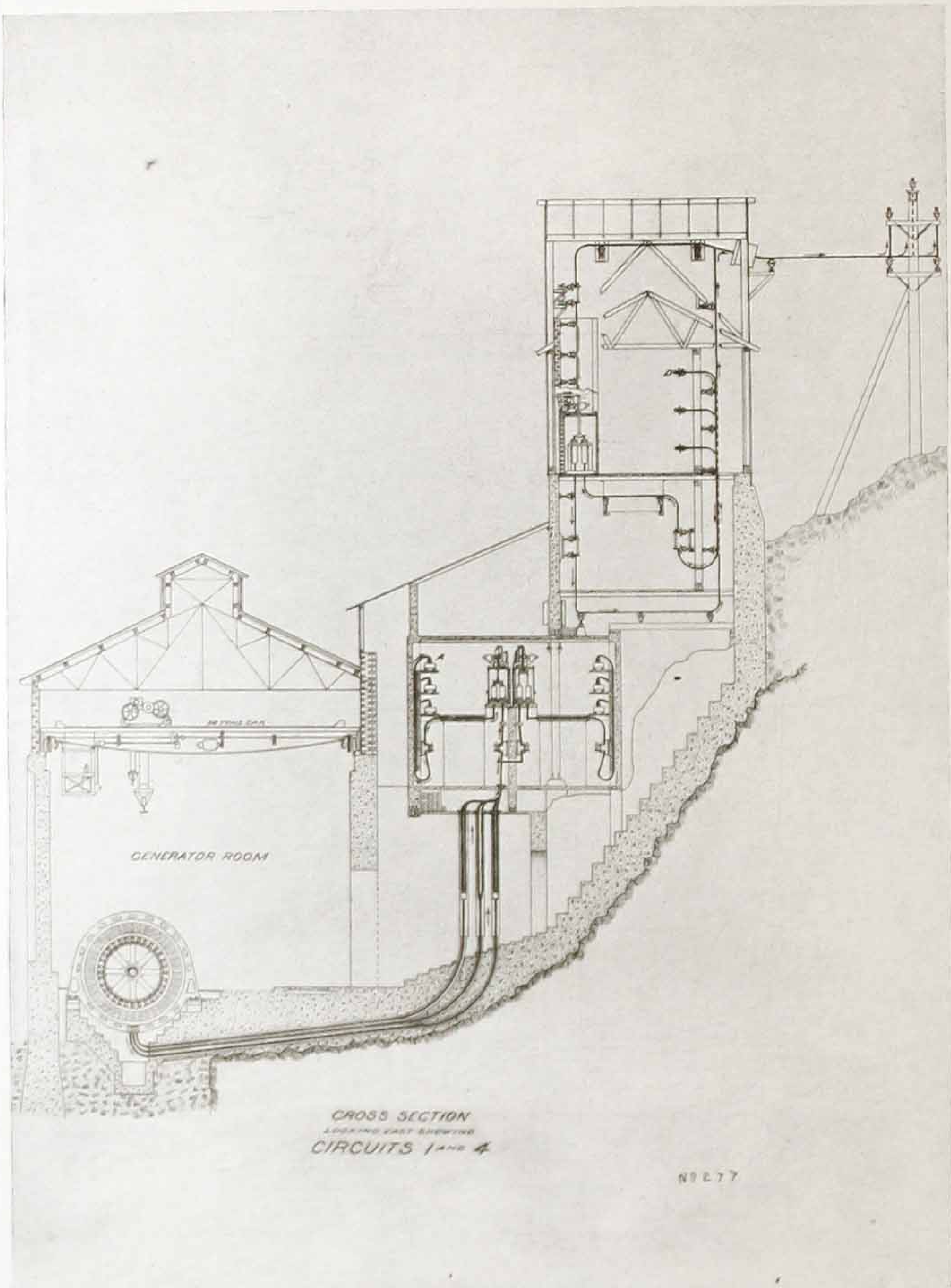
Each generator panel contains three ammeters, one voltmeter, a polyphase indicating wattmeter, a polyphase integrating wattmeter, and a field ammeter.

Each outgoing line panel contains three ammeters; and the totalling panel contains a power factor indicator, a frequency indicator, a curve-drawing voltmeter, and three curve-drawing ammeters. The curve-drawing instruments belong to a type lately developed by the General Electric Company, giving a record three inches long per hour.

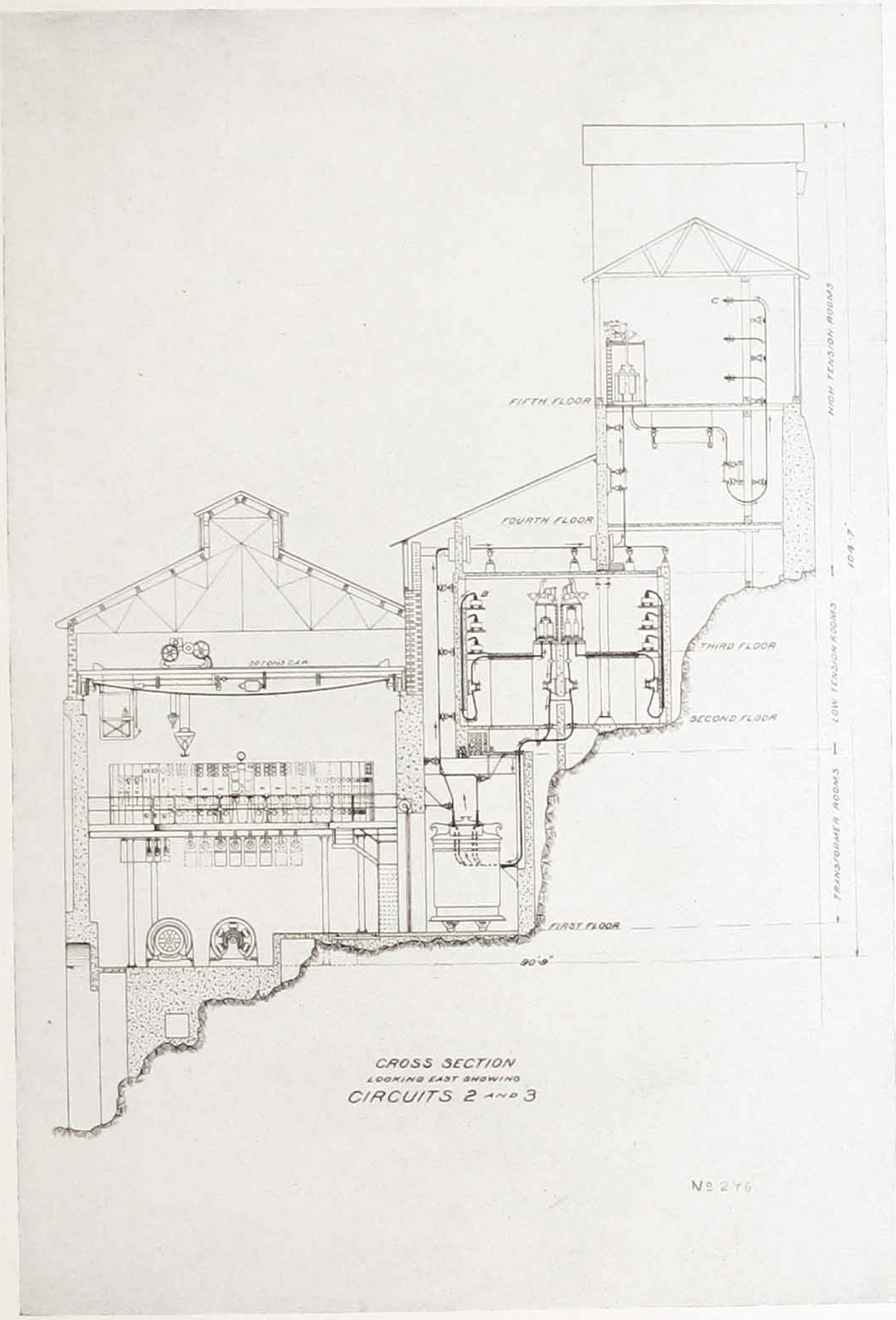
The control of the plant is completely from the switchboard gallery. A water wheel may be started or stopped, a generator brought up to voltage, synchronized with other generators on either bus, a transformer bank cut in on either bus and a transmission line connected in circuit without the presence of a person in the room where the actual switching is done, the lighting of a red lamp indicating the closing of a switch, and a green lamp the opening of a switch.

Switch-house Arrangement.

Accompanying cuts show sections through the generator-room and switch-house. The transformer-rooms are at the same level as the generator-room, but isolated from the latter by rolling steel doors. On floor No. 2 are the low tension disconnecting switches, the generator and transformer cables going to the sets of disconnecting switches on either side of the middle partition, the disconnecting switches installed between the oil switches and the bus being on the outer walls and immediately below the bus bar compartments, which



Cross Section Power House through Tower.



Cross Section Power House, showing Switchboard.

are above on floor No. 3. In the centre of floor No. 3 are the low tension oil switches, the two oil switches corresponding to a generator or transformer bank being arranged back to back, and facing their corresponding set of bus bars. The bus bars are of the laminated type, consisting of flat copper bars, with expansion joints and supported on marble slabs set on edge, which in turn rest on concrete slabs forming barriers between adjacent bus bars. The compartments formed by the concrete slabs are to be covered by insulating fireproof doors.

The oil switches are installed in brick cells, with soapstone bottom and top slabs and doors. Each pole of a switch is separated from the other poles by brick barriers.

The same general scheme is used for both the low and high tension disconnecting switches and oil switches, except that only one set of high tension bus bars is at present installed, provision being made for the later installation of the second set. The high tension disconnecting switches and current transformers are on floor No. 5, while the high tension oil switches are on floor No. 6. Above floor No. 6 are the two outgoing high tension line towers, in the north end of which are the high tension lightning arresters, each pole being separated from its adjacent pole by brick barriers extending the full length of the arrester. The lines emerge from the wire tower centrally through an extra heavy 30-inch sewer tile covered by a glass plate.

Transmission Line.

From the power-house two parallel transmission lines run a distance of 22 miles to Bluffs, a station on the line of the Puget Sound Electric Railway, 9 miles from Tacoma and 25 miles from Seattle. From Bluffs one line runs for a great part parallel to the transmission line of the Puget Sound Electric Railway to Seattle, and one to Tacoma, also parallel to the transmission line of the Puget Sound Electric Railway.

The transmission line of the Puget Sound Electric Railway is at present operating at 27,000 volts; but the line is designed for operation at double this voltage, so that, when this line is changed over to a 55,000 volt basis, there will be two complete and independent pole lines from the power-house to Seattle and Tacoma. At Bluffs there are erected junction pole switches, by which the two transmission lines may be cut through independently, one to Seattle and one to Tacoma, or both lines put in multiple, or any section isolated without interfering with the operation of the other sections.

From the power-house to Bluffs a private right of way has been secured, the two pole lines being from 50 to 80 feet apart. When passing through wooded sections, all dangerous timber has been cleared well back on the land adjacent to the right of way on both sides, so as to completely protect the transmission line.

The minimum length of poles used was 45 feet with a minimum top diameter of 10 1-2 inches. The standard

Transmission Line.

spacing is 125 feet on straight line, and 90 to 100 feet on curves.

The main cross arm is 5″ x 7″ x 7′ 4″ of Washington fir, boiled in raw linseed oil, giving it a much longer life than an untreated arm. This arm is bolted to the pole by two galvanized iron bolts, and braced by a combination wood and galvanized iron brace. At the top of the pole is a 5″ x 7″ x 18″ arm, supported by an angle iron frame bolted to the pole by two galvanized iron bolts.

The main arm supports two insulators, and the top arm one insulator, giving an equilateral triangular spacing of 72 inches between wires.

The pins on one line from the power-house to Bluffs, and from Bluffs to Seattle and Tacoma, are galvanized malleable iron, cast hollow and circular in cross section, and having a shank diameter of 2 1-2 inches. The pins on the other line are of the same general exterior form and dimensions, but turned from eucalyptus wood and treated with linseed oil. The iron pins and eucalyptus pins are entirely interchangeable in all parts of the construction.

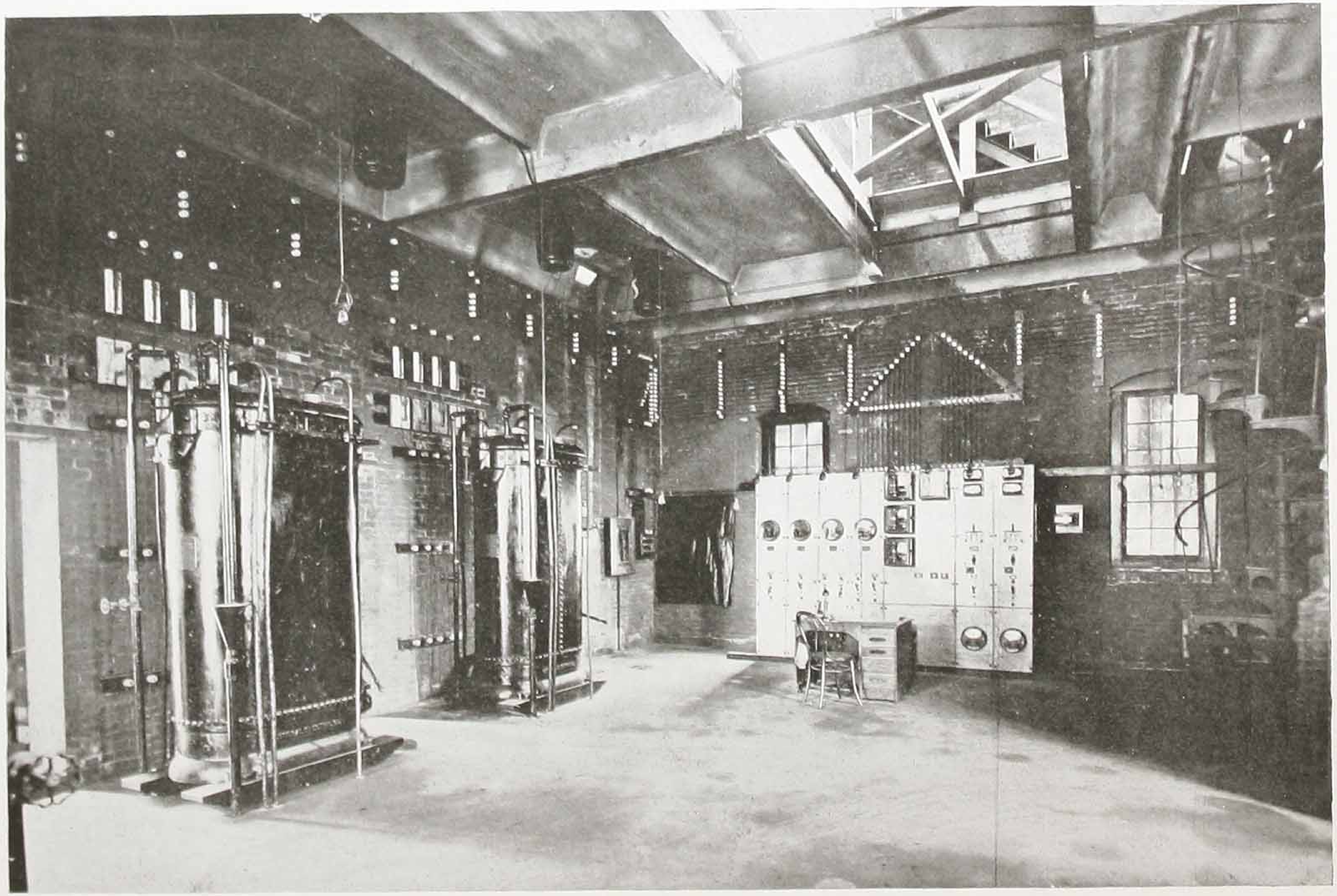
The insulators are of dark brown glazed porcelain, part being furnished by the Locke Insulator Manufacturing Company, and part by The R. Thomas & Sons Co. The insulators are a special design adopted after tests on a number of samples of varying design. The insulator consists of a broad umbrella-shaped top 14 inches in diameter, and three inner shells cemented together and

to the iron pins by neat Portland cement. They weigh about 22 pounds, and stand a potential of 90,000 to 100,000 volts before arcing over under an artificial rain test. The separate parts of the insulators were given a dry potential test at the factory before shipment; and, after assembly in Tacoma and before shipping out on the line, they were again tested to a potential corresponding to the dry arcing over voltage. So far the behavior of these insulators under the weather conditions that have existed since the plant was put into operation, and under a line voltage of 55,000 volts, has been entirely satisfactory.

The line wire on both lines from the power-house to Bluffs, and from Bluffs to Seattle, is 19-strand 4-0 semi-hard-drawn copper cable, and from Bluffs to Tacoma is solid 1-0 semi-hard-drawn copper wire.

The wires are transposed, making a third of a turn about every four miles.

The telephone line is supported on cross arms 7 feet below the main arm, and consists of two No. 10 hard-drawn copper wires, transposed every tenth pole, the glass insulators being double petticoat deep groove on locust pins. The operation of the telephone line with the above construction has been entirely satisfactory. The company also has an independent telephone line leased from the Sunset Telephone Company, and constructed over another route.



Massachusetts Street Sub-station. Switchboard and Compensators.

Sumner and Puyallup.

Eighteen miles from the power-house and along the transmission line from the power-house to Bluffs is the town of Sumner. In Sumner a sub-station has been built to accommodate two 100 kilowatt, 50,000 to 2,300 volt transformers for local power and lighting, one of which is now installed.

A 2,300 volt line has been built from this station to Puyallup, a distance of three miles, for supplying the city of Puyallup with current for lighting and power.

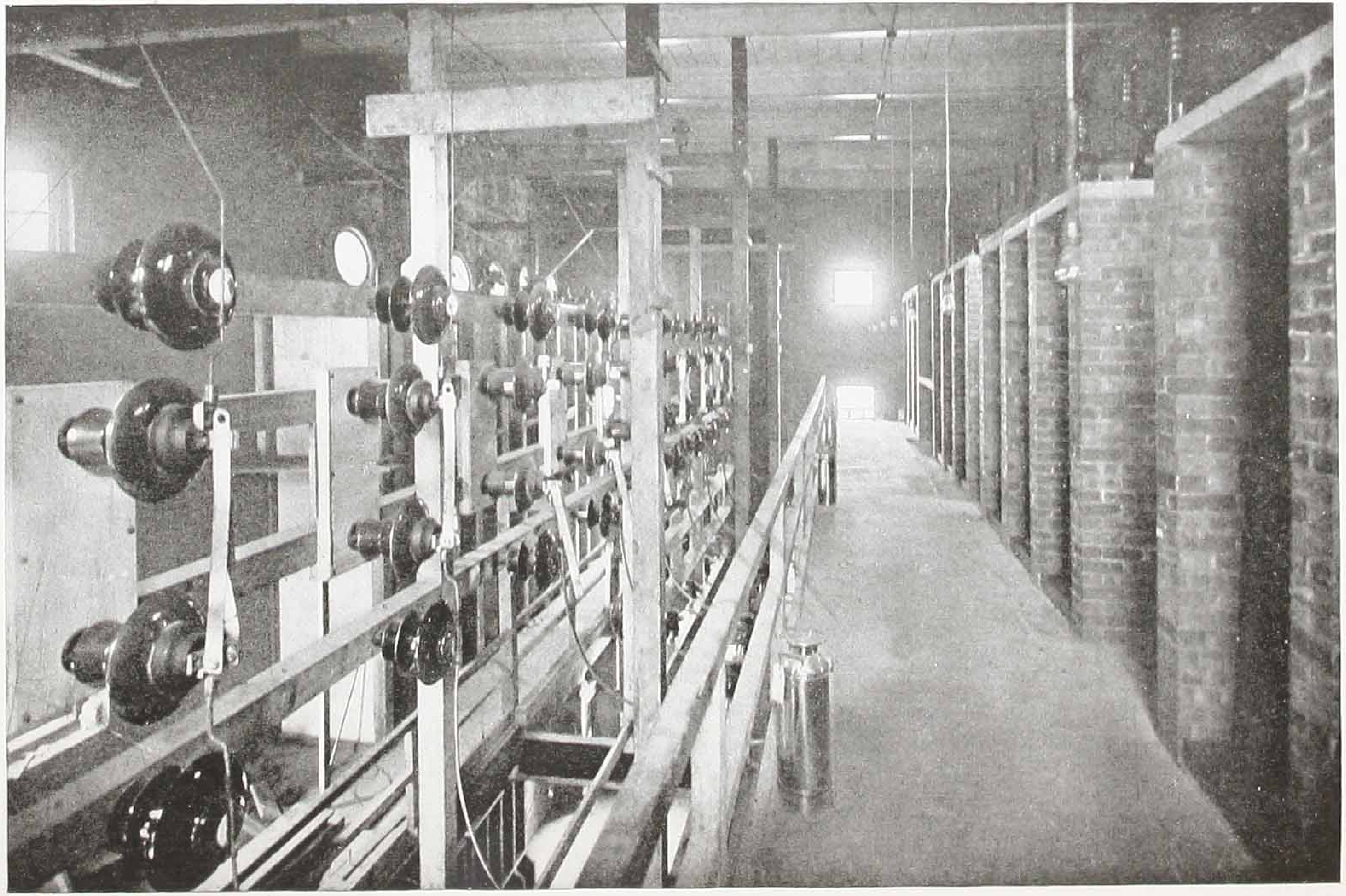
Massachusetts Street Sub-station.

The receiving station in Seattle is built on Massachusetts Street, near the southerly city limits. Here the high tension current is stepped down to 2,300 volts for local distribution to the stations of The Seattle Electric Company.

Control is provided by means of motor-operated oil switches for the two incoming high tension lines, for two 4,000 kilowatt banks of transformers, and for three outgoing 2,300 volt feeders. The control of the transformers consists of a motor-operated, 60,000 volt, 400 ampere oil switch on the high tension side of each bank of transformers, and a motor-operated 2,500 volt, 4-pole oil switch on the low tension side of each bank. The control of the 2,300 volt outgoing feeders is by motor-operated, 4-pole oil switches, similar to the

transformer low tension switches, differing only in capacity; the former being 800 ampere, and the latter 1,200 ampere capacity. All of the oil switches have time-limit relays for automatically opening the switches in case of overload or short circuits. There are installed four 2,000 kilowatt transformers in two banks of two each, transforming from 50,000 volts three-phase to 2,300 volts two-phase. The arrangement of the windings is such that 50,000, 40,000, and 25,000 volts can be used on the high tension side, and low tension voltages of 13,800, 6,900, and 2,300 volts may be obtained. The two transformers constituting a bank are connected T, but using the full winding in the teazer transformer rather than 87 per cent., as in the usual Scott three-phase to two-phase connection. This produces only 1,990 volts on the low tension side of the teazer transformer, with 2,300 volts on the main transformer; and, in order to boost this to normal, a 200 kilowatt transformer called a compensator, having the full ampere capacity, in the boosting coil, of the 2,000 kilowatt transformer and a ratio of transformation of 1,990 to 310, is installed. This makes it possible to omit all 87 per cent. taps on the high tension winding, of which there would be a number, for the three primary voltages above stated, and simplifies the transformer construction.

All the transformers, including the compensators, are water-cooled, the water for cooling being primarily derived from the city service, but recooled by a cooling tower to effect economy by the reuse of water.



Massachusetts Street Sub-station. High Tension Wiring and Disconnecting Switches.

There are, in addition to the above apparatus, two 500 kilowatt transformers in this station, with a ratio of transformation of 25,000 to 2,200 volts, installed for connection to the transmission line of the Puget Sound Electric Railway.

For measuring the input of power into the 2,300 volt busses, a graphic recording voltmeter, ammeter, and wattmeter are provided in addition to the integrating wattmeter.

Lightning arresters, identical with those at the power-house, are provided for each of the incoming lines. Marble barriers between adjacent poles of the arresters are installed to prevent the travelling of an arc from one leg to another.

Four-pole static dischargers are installed on the low tension side of each transformer bank, their purpose being the same as those at the power-house.

For controlling the voltage of the 2,300 volt outgoing feeders there is installed in each feeder a motor-operated induction regulator, each of a capacity of 340 kilowatts. These regulators boost or lower equally each leg of each phase.

Seattle Electric Company's Distribution.

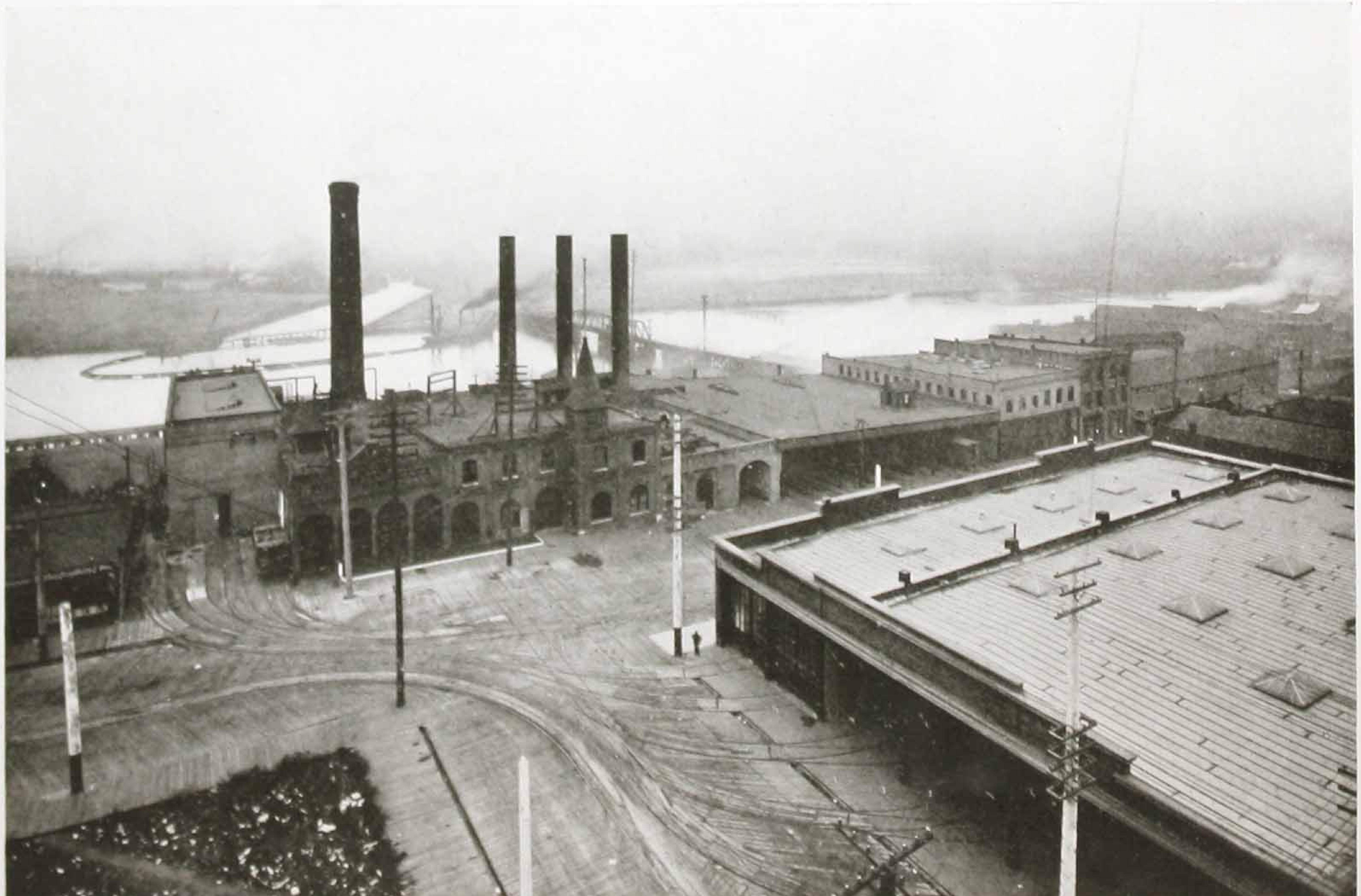
The power is transmitted at 2,200 volts, two-phase, from Massachusetts Street sub-station to Post Street Station, and from there also at 2,200 volts, two-phase, to James Street Station and Fremont Sub-station.

Post Street Station contains nine 500 kilowatt rotary converters, each with two 300 kilowatt transformers, five giving 500 volt current for railway, and four 250 volt current for lighting; also six 50 kilowatt tub transformers for street lighting. This station is a steam relay station, and contains two 2,500 kilowatt overload capacity, 60 cycle, 2,200 volt, two-phase alternators, each driven by a vertical compound McIntosh & Seymour engine, also a 1,000 kilowatt lighting and a 500 kilowatt railway battery. The station contains the general switchboard for controlling the whole distribution in Seattle.

James Street Station contains two 300 kilowatt induction motor generator sets, giving 500 volt railway current. It is also a steam relay station, with three 150 kilowatt railway generators, driven by a double Corliss engine. When operated on a water-power basis, the railway generators are used as motors to operate the James Street cable road.

Fremont Sub-station contains two 300 kilowatt motor generator sets, one induction and one synchronous, the motor end of each being 2,200 volts, two-phase, and the generator end 500 volts, direct current. There is also installed a 300 kilowatt railway battery.

The Seattle Electric Company has, in addition to the above, two steam relay stations not used as sub-stations. These are equipped with direct current machinery for railway and light, and have a combined capacity of 1,500 kilowatts.



Power Plant of the Tacoma Railway and Power Company. Sub-station on Lett.

TACOMA SUB-STATION.

The receiving station in Tacoma is a new brick building, built adjacent, and as an addition, to the steam station of the Tacoma Railway & Power Company. Control for two incoming high tension lines is provided as described for Massachusetts Street Sub-station. One 4,000 kilowatt, 50,000 to 2,300 volts transformer bank is installed with automatic oil-switch control on high and low tension sides.

There are also installed two 500 kilowatt step-up transformers, transforming from 2,300 volts, two-phase, to 13,800 volts, three-phase, for supplying power to Fern Hill Sub-station, the Northern Pacific Railway Company's shops, and other local consumption not within the range of economical distribution at 2,300 volts. Automatic control of this bank is provided on the low tension side only by means of a type "H," 4-pole, motor-operated oil switch. Spare transformers for each of these banks are provided.

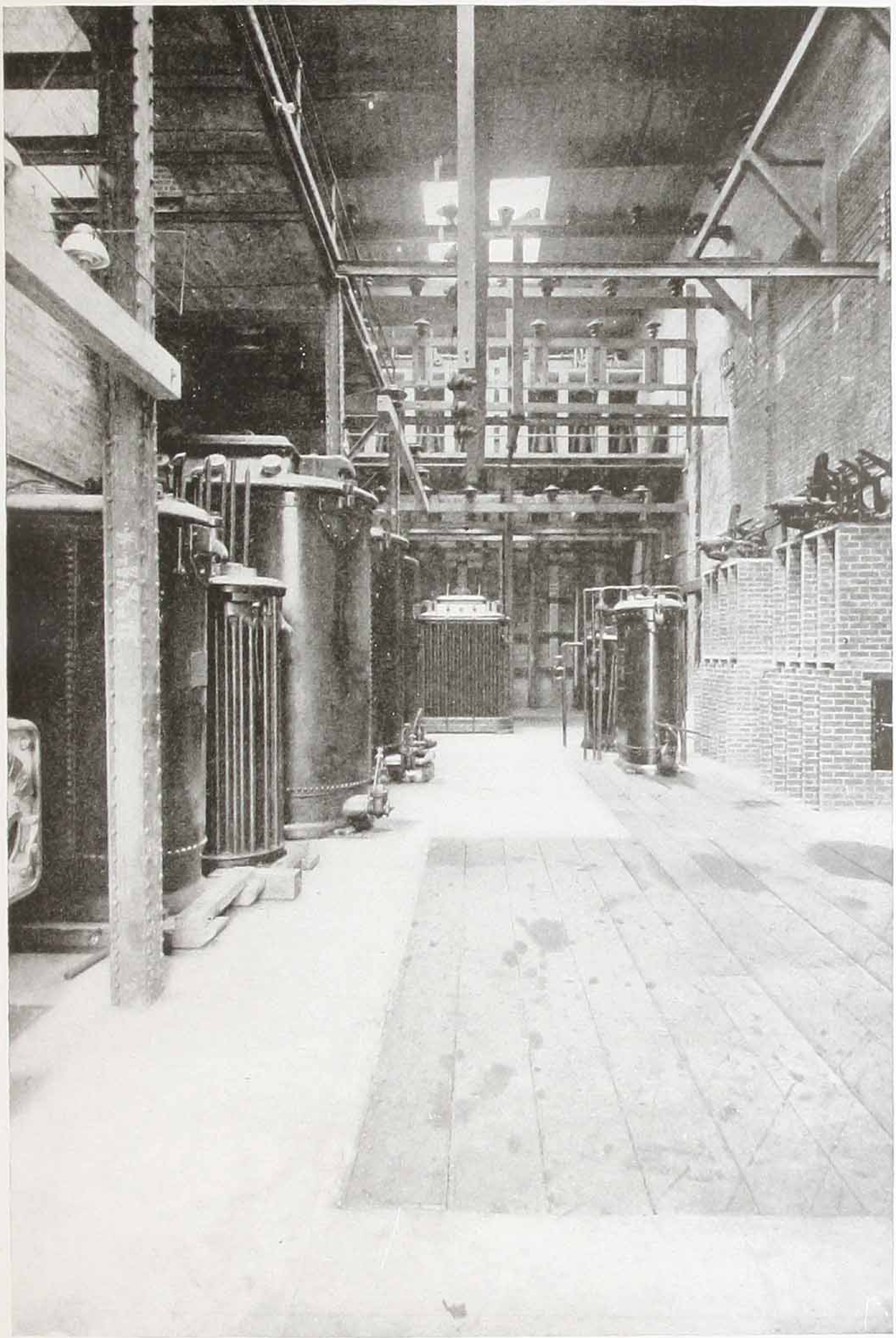
For receiving power from the 25,000 volt transmission line of the Puget Sound Electric Railway, four 200 kilowatt, oil-cooled transformers, wound for 25,000 to 50,000 volts, stepping down from 25,000 to 2,300 volts, are installed.

The high tension oil switches are installed on a steel concrete gallery, 20 feet above the transformer-room floor, the two line oil switches on a gallery at right angles to the length of the building, and the transformer switch

on a gallery parallel to the length and along the north wall of the building. Directly under the transformer oil switch are the transformers themselves. On the opposite side of the room and parallel to its length, and four feet above the floor, are the transformer 2,300 volt oil switches.

One 400 kilowatt induction regulator, similar to those installed in Massachusetts Street Sub-station, controls the potential of the supply bus, being installed between the transformer bus and the supply bus. Apparatus for cooling the transformer circulating water is being installed somewhat similar to that at Massachusetts Street Sub-station.

The 2,300 volt power is used for lighting and power service in the city of Tacoma partly, and partly converted into 600 volt direct current for railway and commercial motor service. This conversion is effected by two 500 kilowatt induction motor-generator sets, by one 850 kilowatt synchronous motor set, and by 800 kilowatts in belted machines driven by a 1,000 kilowatt synchronous motor. Either this synchronous motor or the 1,000 kilowatt motor driving the 850 kilowatt D.C. generator can be driven by the steam engines which drive on to a line shaft in which these motors are set, being connected at either end by jaw clutches, thus furnishing a supplementary source of supply and reserve for any of the alternating current distribution and for the induction motor-generator sets supplying current for the railway. A 100 horse-power induction motor furnishes power for



Interior Tacoma Sub-station.

driving a cable road accommodating the hill district of the city.

The Tacoma Railway & Power Company operates about 84 miles of track in the city of Tacoma, and between Tacoma and the neighboring towns of Puyallup, Spanaway, and Steilacoom, and also furnishes power for the operation of the trains of the Puget Sound Electric Railway within the Tacoma City limits.

At the Fern Hill junction of the Puyallup and Spanaway lines is a steam station of 500 kilowatt capacity. There is being installed in this station a 500 kilowatt synchronous motor-generator set, supplied from the substation above described by a 13,800 volt transmission line. This same transmission line supplies current for the operation of motors and lights at the shops of the Northern Pacific Railway at South Tacoma, and for the operation of induction motors, driving air compressors, working a Bohle air-lift system, pumping water for the Tacoma City Water Supply, near South Tacoma, and for operating a large number of other stationary motors used by various manufacturing concerns.

System of Puget Sound Electric Railway.

The Puget Sound Electric Railway operates an interurban third-rail system between Seattle and Tacoma, traversing the White River valley, a distance of 36 miles, and also a branch line reaching the town of Renton. 600 volt direct current is supplied to the third rail through

three sub-stations located at Georgetown, Kent, and Milton.

Each sub-station contains a bank of transformers stepping down from 25,000 volts, three-phase, to 2,300 volts, two-phase; also a 300 kilowatt induction motor-generator set, and a storage battery having a rating of 384 kilowatts on the hour basis. Oil-switch control is provided on both the high and low tension sides.

From Kent Sub-station is operated the city lighting systems of Kent and Auburn, a transformer, separate from those feeding the motor-generator set, being provided for supplying this 2,300 volt service.

These sub-stations are supplied from the 25,000 volt transmission line previously mentioned, this line having the 25,000 volt transformer relay at both the Seattle and Tacoma ends. When this line is operated at 50,000 volts, transformers for this voltage will be installed in all the sub-stations.

Auxiliary and Relay Apparatus.

The electrical development has been designed primarily to insure uniform and uninterrupted service. Continuity of service has been insured by the greatest solidity of construction in every part, by duplicate busses and switches at the power-house, duplicate transmission lines and spare transformers at each end of transmission line, so that all repairs can be made without discontinuing service, and by having in all the electrical ma-

chinery an overload capacity of from 25 per cent. to 50 per cent.

In addition to this there are in reserve in Seattle and Tacoma six steam plants of 10,000 kilowatt aggregate capacity and six storage batteries of 2,700 kilowatt aggregate capacity, all electrically interconnected with each other and with the water-power plant, and ready for supplementary and relay service.